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Agricultural Memorandum No 959

FORECASTS FOR SPRAYING CONDITIONS - RESULTS OF A PRELIMINARY TRIAL

by H A Douglas

BACKGROUND

Following the increasing awareness by farmers, growers and advisers of the damage and cost resulting from spray drift, work was undertaken to prepare guidelines. One line of work has culminated in a series of Agricultural Memoranda (Nos 907, 908, 937, 951) and other such articles (eg joint information document by Rutherford & Thompson). This latter document summarised some of the earlier work and laid down ground rules for establishing whether drift was a hazard under a given set of conditions. The remaining problem was whether a forecast, with sufficient accuracy and detail, could be issued on an operational basis. ADAS were very keen to establish such a service and a joint trial was established (at short notice) to provide the necessary information.

ORGANISATION OF THE TRIAL

The project (trial) area was identified as Worcestershire/south Warwickshire. This was selected since it represented the approximate size of area that ADAS wished to be covered by a single forecast, in an operational scheme. It also had a recent history of spray drift damage. The trial posed two questions. Firstly, would the forecasts be sufficiently precise to provide reliable guidance on whether to spray or not (spray drift is not the only consideration)? To be successful, the forecast must be an improvement on other area forecasts presently available. Secondly, would the benefits from such a service show a net profit in economic terms? The problems of dissemination of the forecast and the responsibility for an operational service were recognised but were left until a later stage. ADAS assumed responsibility for tackling the second of these questions and this paper looks at the first question.

Nine individuals or organisations agreed to cooperate in this pilot project. They each completed a daily questionnaire (Annex A) of which questions 4-7 gave a qualitative assessment of the forecast. Two, who used the standard ATWS forecast, acted as a control group. Of the remaining seven, four were based at climatological stations and these were asked to undertake additional observations and complete the data sheet (copy as Annex B). In addition, data were obtained from a Didcot automatic weather station (AWS) at Wellesbourne (NVRS) and a TSR at Drayton EHF. After the trial period, Birmingham analysed their own airport forecasts on the same basis to give

an indication of the difference in levels of precision for a site-specific forecast compared to a forecast for an area.

Agreement was reached with Birmingham Airport for a special forecast to be issued daily during April and May (the trial actually ran from 5 April to 28 May) by Telex to the MAFF Worcester Office, with the cooperating observers telephoning Worcester for the details. The forecasts, issued by 0700 hours (all times in this document are British Summer Time) for the period 0800-2100 hours the same day, were designed to include the following details:-

- 10 m wind speed and direction
- atmospheric stability (through cloud amounts)
- maximum temperature and possibility of frost
- rainfall (amount/intensity and timing)
- surface moisture (eg slow evaporation of overnight dew)

RESULTS

General:

Only one forecast failed to arrive on time but not all forecasts gave all the detail originally requested. More importantly, however, for this analysis, some observers found it difficult to provide a full set of quantitative data to enable the comparisons to be undertaken. As a result, some of the conclusions are based on limited data and some comparisons were not attempted.

A scoring system was devised (details in Annex C) to try and judge the success of the forecast in meeting the specific criteria required for spraying. Thus the choice of cut-offs was not uniformly distributed and the scoring reflects only this requirement. A net positive score for an element indicates a useful forecast. During the trial, the forecasters were unaware of the scoring system to be used - thus there was no tendency to forecast "safe" to maximise the score.

The rest of this paper will present the results, element by element, and the self-analysis by Birmingham. The project team involved have studied the results and recommended several changes should this be repeated in 1983. These recommendations and their reasoning are not included in this paper. It should be noted that following an inspection of all sites, all data involving wind observations from the northerly sector at one station were disregarded because of severe over-sheltering. For other aspects at that station and at other sites the equipment was correctly exposed and properly maintained.

Qualitative Assessments:

This was a general survey and its main task was to provide a comparison with the control group. The results are summarised in Table 1 (a) and it is clear that there appears to be a 5% improvement over the ATWS and that both groups identify rainfall and wind speed as the two main reasons for faulting a forecast. In passing, attention is drawn to Table 1 (b) which summarises some of the results of the corresponding ADAS Study*.

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* Experimental forecast for ground crop spraying of herbicides. MAFF, ADAS Research and Development Reports, Agricultural Service, Cereals, 1982 (published Autumn 1983).

Wind Speed:

Two comparisons were undertaken. A copy of the forecast was received at Wolverhampton and forecast wind speeds for 1000, 1300 and 1700 hours were assessed based on the data given. This represents the understanding on which the observer would judge the forecast.

Table 2 (a) (i) gives the combined matrix comparison of these forecast values and the values recorded by the observers, who followed their normal climatological observational practice. Because of the difficulties (week-ends, public holidays, etc) there were many more 1000 hours observations than at the other two times. There is broad agreement but some errors are obvious. When the scoring system (detailed in Annex C) is applied to the data, the result is Table 2 (a) (ii). This shows an improvement in accuracy over the three observing times. In general, the majority of the 1000 hours - errors were underestimates and the 1700 hours - errors, overestimates of the actual wind.

Wind at 10 m is not that which affects the spray droplets and a similar exercise was carried out using the 2 m high wind recorded by the Didcot AWS at Wellesbourne. The 10 m forecast winds were reduced to 2m equivalents by the conversion

$$(\text{2m wind}) = (\text{10m wind}) \times \frac{\ln (2m/0.02m)}{\ln (10m/0.02m)}$$

In this case the AWS value was taken as the mean wind speed in the hour ending at 1000, 1300, 1700 hours respectively and because of the different values involved a different scoring system was used. The results are in Table 2 (b) and are in direct contrast to those above in that the accuracy of the forecast decreases rather than increases during the day. The fact that this is based on a mean hourly wind rather than a spot observation, and the different scoring system may account for some but not all of the change. It is significant that the majority of serious errors in the 1300 and 1700 hours comparison were through overestimating the wind speed which often fell away during the afternoons.

It is the wind speed near the boom height that is critical so Table 2 (b) probably reflects the true usefulness of the forecast better than Table 2 (a) (ii). Some run-of-wind cup counters were installed but many readings were missed so no analysis is presented. The few observations received support the findings of the AWS.

Wind Direction:

Only two observers specified wind direction as the reason for faulting a forecast but the results in Table 2 (c) clearly show that, for the accuracy required, the forecasting of wind direction was less successful than wind speed. The scoring is harsh, but wind direction is one of the (if not the) most critical factors in assessing drift risk and the cut-offs used (see Annex C) were considered to be realistic targets on which to judge the success of the forecast. Local topography is obviously a major influence and users may have to gain experience in "building-in" local offsets, to make the most use of the forecast.

Maximum Temperature:

Compared with the two previous factors, maximum temperature is less critical

and the tolerances are suitably set, and the result is a much higher accuracy. The details are given in Table 2 (d).

The systematic underestimate of temperature is considered to be due to the fact that when preparing the forecast, the air-field forecast had just been completed, and the maximum temperature was given without due regard to altitudinal differences. For this purpose such an error is not critical.

Ground Frost:

A forecast of ground frost was to indicate that frost was expected to continue into the forecast period. It did not refer to the subsequent night. No true comparison could be made since the only available data was the climatological grass minimum. As a consequence, the results shown in Table 2 (e) are considered satisfactory.

Rainfall:

The forecasts gave insufficient guidance on timings to allow any useful comparison. The results of the analysis of the amount/intensity and duration (short showers, continuous precipitation) are given in Table 2 (f). It should be noted that, resulting from a blocking high for much of the period, the rainfall comparison cannot be considered fully representative of normal conditions. The results show that, for the accuracy required, the success in forecasting rain was similar to that for wind speed and both were superior to wind direction.

Others:

The returns gave insufficient data to allow assessments on surface wetness or state of sky to be undertaken.

Birmingham Comparison:

After the trial, the forecasts (issued at a similar time) for Birmingham Airport itself were analysed and scored on the same standard. The results are given in Table 3. It will be seen that for all elements, there is a higher score. This is to be expected as a forecast for a specific site should always score higher than one for a general area. The Birmingham values represent the maximum success that could be expected by an individual using the consultancy service for a given site.

SUMMARY AND CONCLUSIONS

The trial was set up at short notice and the results have illustrated shortcomings in the design and implementation of the trial and these have been noted. It must be noted that the conditions during the trial were about as favourable as possible to the forecasters and the results quoted are probably towards the best that can be expected using current forecasting techniques.

Nevertheless, the trial did indicate that the forecasters were able to meet the strict tolerances required to make this forecast useful and the

scheme seemed to be an improvement on the ATWS. However the three poorest elements were wind direction (only just successful), wind speed and rainfall and these are the three most critical elements in any spraying decision. Thus it would be wrong to conclude that this trial has conclusively proved the advantages of such a specific forecast for an area similar to that covered in the trial.

ACKNOWLEDGEMENTS

The co-operation of the field observers and the staff at Birmingham Airport is gratefully acknowledged. Particular thanks is due to I McCaskill, S Met O Birmingham, for his active involvement and his compilation of the Birmingham comparison.

Any comments or suggestions on this paper should be referred to the author.

Meteorological Unit
MAFF, Woodthorne
Wolverhampton

August 1982

REFERENCES

Adams R J 1981 "Weather and Spray Drift: Part I: Some misconceptions" Agricultural Memorandum 907 (Unpublished Met Office Memorandum).

Rutherford I and Thompson N 1981 "The Formation and Movement of Agricultural Sprays". (Unpublished Information Leaflet, joint ADAS (Silsoe) & Met Office).

Thompson N 1981 "Weather and Spray Drift: Part II: Some quantifications". Agricultural Memorandum 908 (Unpublished Met Office Memorandum).

Thompson N 1982 "Weather and Spray Drift: Part III: maximum likely rates of uptake of volatilised chemicals on downwind surfaces". Agricultural Memorandum 937 (Unpublished Met Office Memorandum).

Thompson N et al 1982 "Weather and Spray Drift: Part IV. Estimating spray drift using a random-walk model of evaporating drops: the model, and some preliminary results". Agricultural Memorandum 951 (Unpublished Met Office Memorandum).

TABLE 1

QUALITATIVE ASSESSMENTS OF THE FORECASTS (See Annex A for questionnaire)

a) Meteorological

	No of observers in group	No of assess-ments	No given as "about Correct"	As % of Total	Range of replies	Reasons for errors (as % of total errors)		
						Wind Speed	Rainfall	Others
Main Group (Special Forecast)	6	218	163	75	67%-82%	37	46	17
Control Group (ATWS Forecast)	2	102	71	70	69%-71%	31	59	9

b) Use of Forecasts

	Wellesbourne		Drayton		Moreton Morrell		D Hodges		Total	
(i) No of forecasts considered	32		25		10		45		112	
(ii) No of days on which forecast changed the spraying decision	6		2		0		17		25	
(ii) as % of (i)		19		8		0		38		22
(iii) Change justified by subsequent weather	4		1		0		13		18	
(iii) as % of (ii)		67		50		0		77		72
(iii) as % of (i)	13		4		0		29		16	

Observers : Wellesbourne – National Vegetable Research Station

Drayton – Experimental Husbandry Farm

Moreton Morrell – Warwickshire College of Agriculture

D Hodges – Commercial Spraying Contractor

TABLE 2

QUANTITATIVE ASSESSMENTS OF THE FORECASTS

See Annex C for scoring systems

a) Wind speed (10m) estimated by observer

(i) All times combined

		Forecast Speed (Kts)				
		0-3	4-7	8-11	12-16	⩾17
Obs. value (Kt.)	0- 3	16	25	16	7	2
	4- 7	18	36	28	13	4
	8-11	8	33	32	20	5
	12-16	3	15	25	26	5
	⩾17	-	5	18	23	8

(1 entry per observation)

(ii)

	Time (BST)			Total
	1000	1300	1700	
+ 1	91	56	62	·209
0	46	24	21	91
- 1	47	24	21	·92
Score	+ 44	+ 32	+ 41	+ 117
% of possible	24	31	39	30

(1 entry per observation)

b) Wind Speed at 2m - measured by AWS at Wellesbourne

Forecast (10 m) winds reduced to 2m by -

$$(\text{2m wind}) = (\text{10m wind}) \times \frac{\ln (2\text{m}/0.02\text{m})}{\ln (10\text{m}/0.02\text{m})}$$

	Time: Hour ending at (...) BST			Total
	1000	1300	1700	
+ 1	27	28	21	76
0	14	8	16	38
- 1	5	9 *	10 *	24
Score	+ 22	+ 19	+ 11	+ 52
% of possible	48	42	23	38

* Of these 19 events - 14 were for forecasts overestimating wind speed. (6 - for 1300; 8 for 1700).

c) Wind Direction

Observed or measured

	Stations				Total	As measured by AWS (2m) at Wellsbourne
	Pershore	Drayton	Wellsbourne	Moreton Morrell		
+ 1	25	27	23	17	92	20
0	14	6	14	15	49	13
- 1	5	8	4	7	24	5
- 2	3	2	6	7	18	6
Score	+ 14	+ 15	+ 7	- 4	+ 32	+ 3
% of possible	30	35	15	- 9	17	7

1) Observations made at 1000, 1300, 1700 (BST) where possible.

2) AWS score based on period 0900 - 1800 BST.

d) Maximum Temperature

/1 entry per station-day/

Distribution of maximum temperature differences (all stations combined).

Difference (D) = Forecast - Actual

Difference (°C)	+ 5	+ 4	+ 3	+ 2	+ 1	0	- 1	- 2	- 3	- 4
No of observations	2	1	1	4	17	46	65	45	15	7

Mean difference = -0.9°C

Score = + 108 (58% of possible)

e) Ground Frost /1 entry per day/

			FORECAST	
			Frost	No Frost
RECORDED	Frost	At 3 or 4 Stations	15	6
		At 1 or 2 Stations	1	9
	No Frost		1	22

f) Rainfall Amounts /1 entry per day/

					FORECAST						
					RAIN						No Rain
					Continuous		Showers or Intermittent				
							Widespread		Isolated		
					Heavy or Mod.	Light	Heavy or Mod.	Light or Trace	Heavy or Mod.	Light or Trace	
OBSERVED	RAIN	Continuous	Heavy or Mod								
			Light			1					
		Showers or Intermittent	At 2 or 3 out of 3 Stations	Heavy or Moderate	1		1	1			
				Light or Trace			1	1		3	
			At only 1 out of 3 Stations	Heavy or Moderate							
				Light or Trace				2	3	2	4
	No Rain					2	1	2		4	25

Score = +17 (31% of possible)

TABLE 3

Self Assessment of Forecasts for Elmdon over the Trial Period

(Table prepared by I McCaskill, S Met O Birmingham)

Number of days considered = Maximum score possible = 53

Element	Number of Forecasts scoring				Mean Score	% of possible score	% of possible scores in area forecasts (Table 2)
	+ 1	0	- 1	- 2 *			
Wind Speed	34	13	6	*	+ 29	55	38
Wind Direction	31	13	4	5	+ 17	32	7
Max Temperature	38	13	2	*	+ 36	68	58
Rainfall (amount)	42	1	7	2	+ 31	59	31
State of Sky	43	9	1	*	+ 42	79	-

* Asterisk against an entry means -2 is invalid for that element

Annex A

ANNEX A ADAS/METEOROLOGICAL OFFICE

WEATHER FORECAST FOR GROUND SPRAY OPERATORS - EVALUATION APRIL/MAY 1982

INSTRUCTIONS

ALL SITES - Please complete daily - tick appropriate box

SPRAYING SITES, eg farms, farmers and contractors:

a. Answer question 1, then obtain experimental forecast from MAFF Worcester (0905) 355355, ext 222.

b. Provide person with answer to question 1b/c.

c. Complete questionnaire.

OBSERVATION SITES - Answer questions 4-7 only.

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1. a. Day of week ☐ Date ☐

b. DO YOU INTEND TO SPRAY TODAY? YES ☐ NO ☐

c. IF NO - WOULD YOU SPRAY - subject to crop and soil being either available and/or suitable? YES ☐ NO ☐

2. AS A RESULT OF THE FORECAST WOULD YOU MODIFY YOUR DECISION? YES ☐ NO ☐

3. IF YES, HOW? Spraying brought forward by at least a day ☐

Spray at time different to intended, but on same day ☐

Delay spraying by at least a day ☐

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4. ASSESSMENT OF TODAY'S FORECAST

5. ASSESSMENT OF YESTERDAY'S FORECAST - SAME QUESTIONS

		at about 0900	at about 1300	Yesterday's
a.	ABOUT CORRECT	☐	☐	☐
b.	OVER OPTIMISTIC	☐	☐	☐
c.	OVER PESSIMISTIC	☐	☐	☐

6. IF b. or c. WHY?

WIND SPEED	☐	☐	☐
WIND DIRECTION	☐	☐	☐
RAIN	☐	☐	☐
TEMPERATURE	☐	☐	☐
OTHER, PLEASE COMMENT	☐	☐	☐

7. ANY OTHER COMMENT: (Please indicate when spraying programme completed)

NB: PLEASE RETURN IN WEEKLY BATCHES, ie each Monday, in stamped addressed envelope provided. Thank you.

B J EYERS
ADAS Mechanisation
WORCESTER
March 1982

Annex B

1982 MAFF/ADAS CROP SPRAY FORECAST TRIAL ANNEX B

Meteorological Assessment Sheet

Please complete this form as fully as possible and return it weekly in the pre-paid envelope along with the spray assessment form.

Week commencing Monday .....

Station .....

			MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
EARLY MORNING	Time								
	Wind Speed								
	Wind Direction								
	Run of Wind								
	Cloud Amount								
	Grass minimum								
	State of Surface								
	Present Weather								
	Rainfall	0900 GMT *							
LUNCHTIME	Time								
	Wind Speed								
	Wind Direction								
	Run of Wind								
	Cloud Amount								
	State of Surface								
	Present weather								
	Rain since morning observation	Intensity							
		Duration							
		Amount							
LATE AFTERNOON	Time								
	Wind Speed								
	Wind Direction								
	Run of Wind								
	Cloud Amount								
	State of Surface								
	Max Temp *								
	Present Weather								
	Rain since last observation	Intensity							
		Duration							
		Amount							

* Thrown back as on climatological return (use normal climatological observation).
For other explanatory notes, please see reverse side of form.

Notes on completion of meteorological assessment sheet

1. Time: Please enter exact time (nearest 5 minutes) of observation. Ideal times for observations are 0900, 1300, 1700 (clock times). Where 0900 BST is not possible, the standard 0900 GMT observation should be used.

2. Sat/Sun/PHs: Only the standard 0900 GMT observation is required.

3. Wind speed/wind direction/cloud amount/present weather: Observations and entries as for normal climatological return, but made at each observation.

4. Run of wind: Please just enter figure as read - do not subtract or change units.

5. State of surface: Please indicate whether a crop (or grass) surface is dry, moist (a little moisture) or damp.

6. Rain fall: 0900 GMT*: Standard climatological value thrown back in normal way.
   Intensity: Indicate whether rainfall was drizzle (d) light (l), moderate (m), or heavy (h) or a combination (e.g. d then m)
   Duration: What proportion of time since last observation did precipitation take place. Give length of time (e.g. 2½ hours) or better actual times (e.g. 11-11.30).
   Amount: Taking a reading as normal - BUT RETURN WATER TO GAUGE - DO NOT THROW AWAY.

7. In all cases, omit observations which prove difficult to make or assess.

8. In case of difficulties, please contact:

Alan Douglas
Regional Meteorologist
MAFF/ADAS
Woodthorne
Wolverhampton 0902 754190 Ext 405

ANNEX C

Details of Scoring systems adapted for this study

Note: The system has been designed to test the forecast for the particular requirements of spray drift forecasting and the results are not regarded as valid for other purposes.

a) Wind Speed (10m) (TABLES 2 (a) and TABLE 3)

Scored as per accompanying table.

All speeds in knots.

		FORECAST			
		0 - 3	4 - 7	8 - 11	⩾ 12
OBSERVED	0 - 3	+ 1	0	0	- 1
	4 - 7	0	+ 1	+ 1	- 1
	8 - 11	0	+ 1	+ 1	0
	⩾ 12	- 1	- 1	- 1	+ 1

b) Wind Speed (2m) (TABLE 2 (b))

Scored as per accompanying table.

All speeds in knots.

F = Forecast speed in knots, reduced to 2m.

	Score		
	+ 1	0	- 1
Numerical Difference between forecast and actual values	⩽ 1 kt for F ⩽ 10 ⩽ 2 kt for F > 10	⩽ 3 kt for F < 8 ⩽ 4 kt for 8 ⩽ F ⩽ 12 ⩽ 5 kt for F > 12 but not scoring + 1	greater difference

c) Wind Direction (TABLES 2 (c) and TABLE 3)

If forecast gives - variable direction all day - day omitted from scoring assessment

- variable direction becoming steady (or vice-versa) - only steady direction is scored. (No steady direction scores 0).

- change of direction within forecast period - score is worst case from forecast.

(ie. furthest direction from that forecast is used).

Score is based on worst case (of 3 observations or 2 successive hours on AWS) for each station on each day observations made.

Score as follows:-

+ 1	Direction	⩽	$\pm 22\frac{1}{2}^{\circ}$	from that forecast
0	Direction	⩽	$\pm 45^{\circ}$	from that forecast
- 1	Direction	⩽	$\pm 60^{\circ}$	from that forecast
- 2	Direction	>	$\pm 60^{\circ}$	from that forecast.

d) Maximum Temperature (TABLE 2 (d) and TABLE 3)

Difference (D) ^{o}C = (Forecast - Actual) ^{o}C

All temperature values rounded to nearest whole degree before assessments made.

+ 1	$D \leq 1^{o}C$
0	$2 \leq D \leq 3^{o}C$
- 1	$D \geq 4^{o}C$

Only the numerical value of D is used - the sign is ignored.

e) Rainfall (TABLE 3 and with appropriate adaptation TABLE 2 (f))

Not all possible combinations shown, actually occurred.

			FORECAST				
			RAIN				
			Moderate/ Heavy	Light rain	Occnl Showers	Scattered or or intermittent Showers	No Rain
ACTUAL	RAIN	Moderate/Heavy	+ 1	- 1	- 1	- 2	- 2
		Light rain or Trace	- 1	+ 1	0	- 1	- 1
	No Rain		- 2	- 1	- 1	0	+ 1

f) State of Sky (TABLE 3)

For this - sunny periods and sunny are considered to be synonymous.

		Forecast		
		Cloudy	Bright/sunny intervals	Sunny
ACTUAL	Cloudy	+ 1	0	- 1
	Bright/sunny intervals	0	+ 1	0
	Sunny	- 1	0	+ 1